CHARLES DARWIN UNIVERSITY

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 2, 2016

FINAL EXAMINATION	DURATION
ENG445 – Process Control and Simulation	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

EXAM CONDITIONS

<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.

This is a CLOSED BOOK examination

Any non-programmable calculator is permitted

No handwritten notes are permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
No additional printed material is permitted	1 x 20 Page Book 1 x Scrap Paper Formula Sheet/s Graph Paper

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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Question 1 **(35 marks)**

It is desired to control the exit concentration C_3 of a liquid blending tank as shown in the figure. Using the information below, do the following.

a) Draw a block diagram for the composition control scheme.
b) Derive an expression for each transfer function and substitute the constants with numerical values.

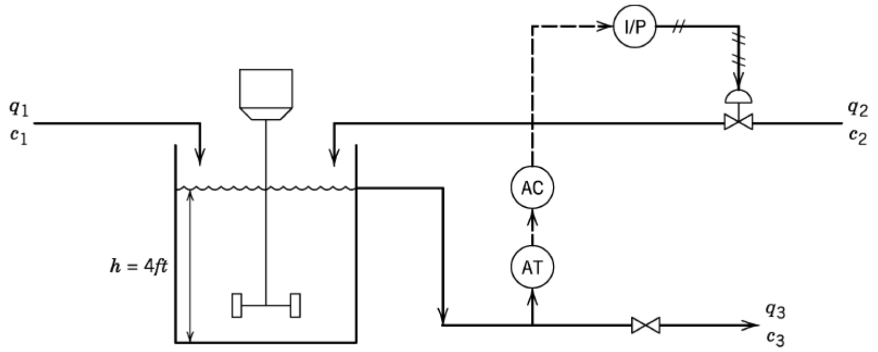


Figure 1

The information of the system is as follow

(i) The tank is perfectly mixed
(ii) An overflow pipe is used to keep the level at 4 ft
(iii) The volumetric flow rate and solute concentration of stream 2, q_2 and C_2, vary with time, whereas those of stream 1 are constant.
(iv) The densities of all streams are the same and constant with time.
(v) A 2 min time delay is associated with the compositions measurement. The transmission output signal varies linearly from 4 to 20 mA as C_3 varies from 3 to 9 $^{lb\ solute}/_{ft^3}$
(vi) The pneumatic control valve has negligible dynamics. Its steady-state behaviour is summarized below where p_t is the air pressure signal to the control valve from the I/P transducer

$p_t\ (psi)$	$q_2\ (^{gal}/_{min})$
6	20
9	15
12	10

(vii) An electronic, direct-acting PI controller is used
(viii) The current to pressure transducer has negligible dynamics and a gain of $0.3\ ^{\mathrm{psi}}/_{\mathrm{mA}}$
(ix) There is a time delay between the temperature of the tank and the reading temperature at AT.
(x) The nominal operating conditions are:

$\rho = 75\ ^{lb}/_{ft^3}$ $\quad$ $\bar{q}_1 = \bar{q}_2 = 75\ ^{lb}/_{min}$

$\bar{C}_3 = 5\ ^{lb\ solute}/_{ft^3}$ $\quad$ $\bar{C}_2 = 7\ ^{lb\ solute}/_{ft^3}$

$\bar{C}_1 = 2\ ^{lb\ solute}/_{ft^3}$ $\quad$ $D = 4\ ft$

Question 2 **(35 marks)**

The figure below shows a typical liquid level control system. Determine the numerical values of k_c and τ_I that result in an stable closed loop system. The level transmitter has negligible dynamics, while the control valve has a time constant of 10 s. Use the following values for your transfer function.

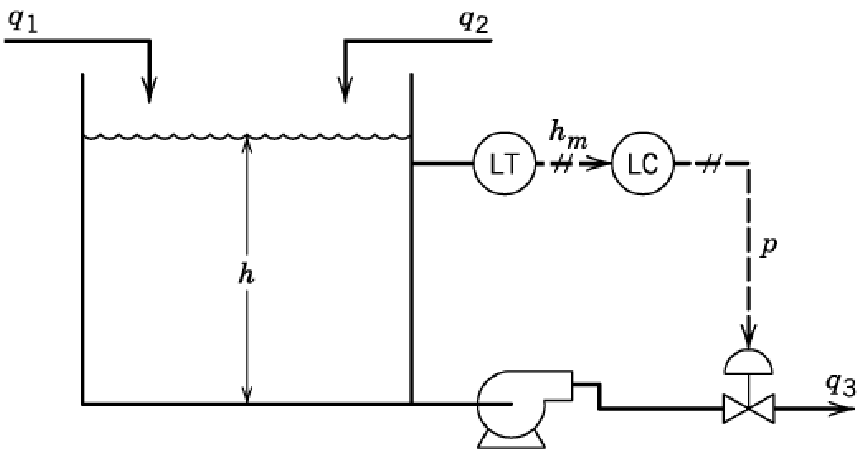


Figure 2

$A = 3\ ft^2$, $\bar{q}_3 = 10\ {}^{gal}/_{min}$, $k_v = -1.3\ {}^{gal}/_{\min mA}$, and $k_m = 4.0\ {}^{mA}/_{ft}$

Question 3 **(20 marks)**

Find the transfer function for the following block diagrams.

a)

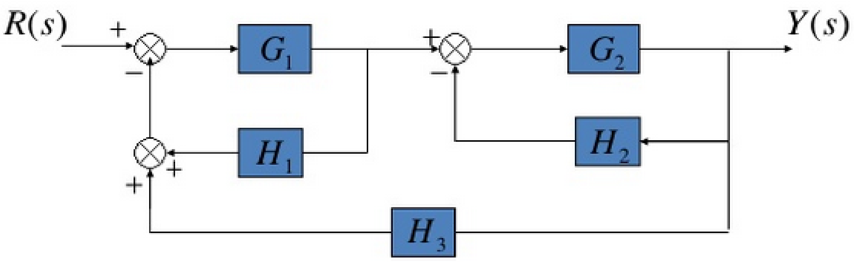


Figure 3

b)

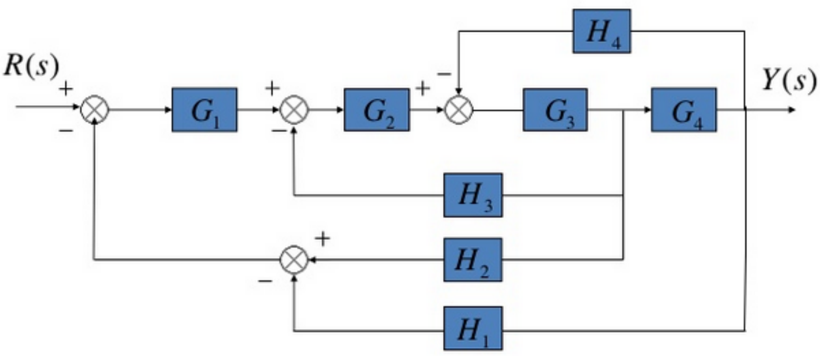
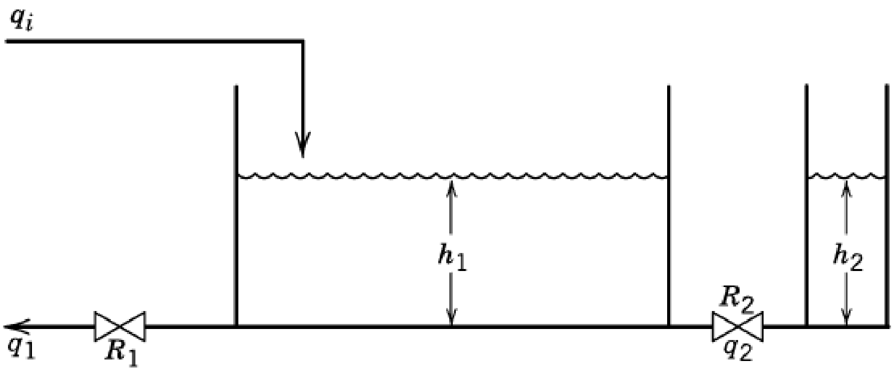


Figure 4

Question 4 **(10 marks)**

Consider the storage tank with sight glass in the figure below.



The parameter values are R1 = 0.5 min/ft2, R2 = 2 min/ft2, A1 = 10 ft2, Kv = 2.5 cfm/mA, A2 = 0.8 ft2, Km = 1.5 mA/ft, and Tm = 0.5 min.

a) Calculate the PI setting parameters by using the Ziegler-Nichols rules
b) What are the gain and phase margins? Assume R2 = 2 min/ft?

The transfer function of the system is given by

$$G_p(s) = \frac{R_1}{(A_1 R_1 A_2 R_2)s^2 + (A_1 R_1 + A_2 R_1 + A_2 R_2)s + 1}$$

Table 12.4 Controller Settings based on the Continuous Cycling Method

Ziegler-Nichols	K_c	τ_I	τ_D
P	$0.5K_{cu}$	—	—
PI	$0.45K_{cu}$	$P_u/1.2$	—
PID	$0.6K_{cu}$	$P_u/2$	$P_u/8$
Tyreus-Luyben†	K_c	τ_I	τ_D
PI	$0.31K_{cu}$	$2.2P_u$	—
PID	$0.45K_{cu}$	$2.2P_u$	$P_u/6.3$

† Luyben and Luyben (1997).